Log Piling Method to Mitigate Liquefaction Damage

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SUMMARY:
Preventing global warming has been one of the urgent issues require imminent attention. The authors propose the use of wood as a construction material to contribute towards effectively reducing the emission of CO_2. A practical example of the usage is log piling as a countermeasure against liquefaction. Small scale shaking table test was conducted to investigate an effect of liquefaction mitigation by log piling into the sand ground. As a result, the method of log piling for liquefaction mitigation is more effective than that of increasing density method such as sand compaction pile method. Effect of improvement is the smaller pile interval, the smaller settlement of the weight on the improved ground.

Keywords: CO_2, Global warming, Liquefaction, Log pile, Shaking table test

1. INTRODUCTION

The 2011 off the Pacific coast of Tohoku Earthquake caused severe damage in Japan. Liquefaction occurred in many places throughout the area with one of the farthest known sites nearly 500 km from the epicenter. The same damage that occurred near the epicenter could also be seen at these distant locations. Since liquefaction is always a serious problem, Japan needs to implement some reasonable measures to mitigate liquefaction damage.

Prior to this Earthquake, the prevention of global warming was of a top priority in this field. It should also be important now. The process of reducing CO_2 due to using wood is as follows: A tree absorbs CO_2 from the atmosphere, releasing oxygen and generating carbon within the wood tissue by photosynthesis. Therefore, the tree size is proportional to the amount of CO_2 reduction in the atmosphere. Increasing the number of trees is equivalent to the reduction of CO_2 concentration in the atmosphere. When the trees are mature, they are harvested and used for various products. As long as tree planting and forest management are carried out well, increasing wood materials aids in the reduction of CO_2 concentration in the atmosphere, just as increasing the amount of trees does.

Since the use of wood is effective for the prevention of global warming, the authors have been considering it to mitigate liquefaction damage, especially since sustainable measures are needed to mitigate earthquake damage. Logs are rarely used in structure foundations. However, at Niigata station, logs were piled into the ground as a foundation and no damage occurred during the 1964 Niigata earthquake in Japan [1]. Meanwhile, a building next to the station had some structural damage. The foundation of this building was that of concrete pile. Incidentally, piled logs are still supporting the Niigata station even now, as they have not decayed.

To verify the effectiveness to mitigate liquefaction damage, the authors conducted a small-scaled shaking table test. Due to the effectiveness of log piling, the authors believe it is a sustainable way to mitigate liquefaction damage while also helping to reduce CO_2 emissions in the atmosphere.

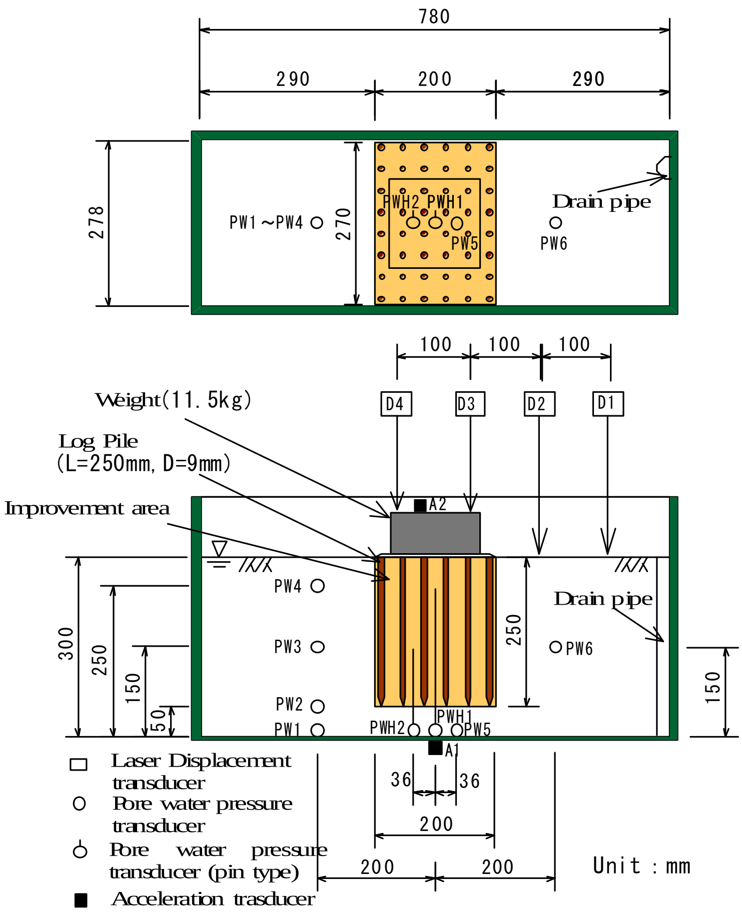


Figure 1. Model ground and sensor arrangement

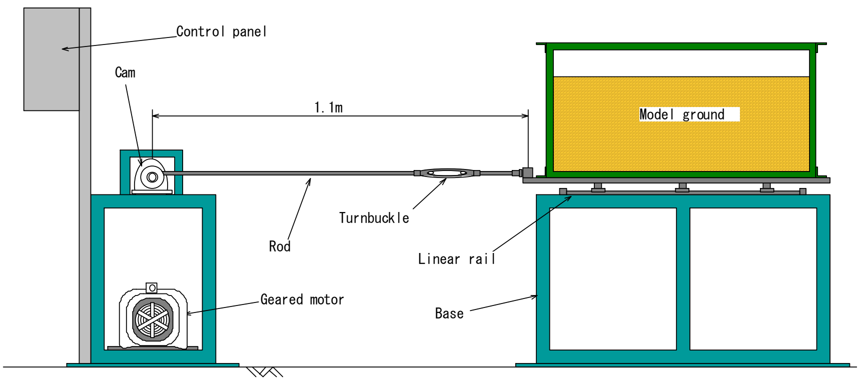


Figure 2. Shaking apparatus

2. OUTLINE OF THE EXPERIMENT

Sand used for the experiment was Toyoura sand (Density of soil particles: 2.645g/cm^3, Maximum void ratio: 0.972, Minimum void ratio: 0.616, 50% grain size: 0.18mm, Uniformity coefficient: 1.6). Figure 1 shows model ground and sensor arrangement. The internal size of the container is 78 cm wide, 40 cm high and 28 cm deep. Initial relative density of the model ground was 50%. The model ground was made by increasing density method, such as sand compaction pile method, and log piling method. Weight of 11.5kg was put on the improved area. This weight is equivalent to a two-story RC building. Log was piled into the model ground to compact one, since log was not structural part, the top of logs was not fixed to the structure. Log with 9 mm in diameter and 25 cm in length were piled into the model ground. Tree species of used log was Japanese cedar. To compare with the ground

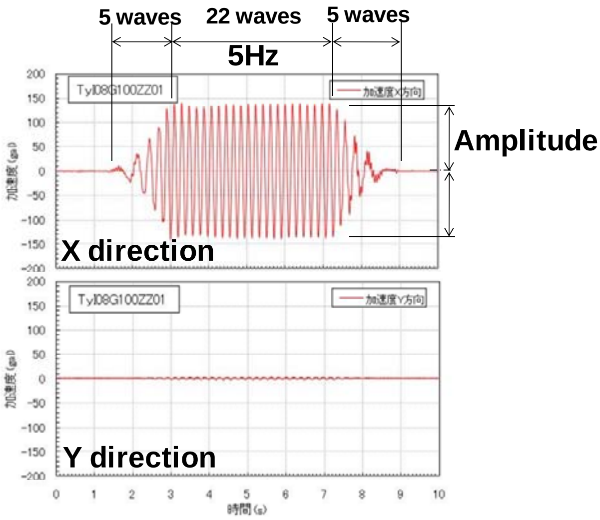


Figure 3. Input motion

improved by increasing density method, a variety of densities of the ground were made and experimented on too. Effectiveness of improvement to mitigate liquefaction was evaluated with settlement of weight on the improved ground surface in this paper.

Figure 2 shows shaking apparatus. This apparatus can shake the container only one way using the rod of 1.1m. Figure 3 shows input motion of x axis direction and y axis direction. Input motion is composed consists of 21 main waves of 5Hz, increasing 5 waves at the start and decreasing 5 waves at the end. It can be understood that amplitude of the y-axis direction is small enough to ignore. Amplitude of the z-axis direction (vertical direction) was small too. Input motion was applied to the model ground changing the amplitude of this wave at each stage 50 gal.

3. PROCEDURE OF MAKING MODEL GROUND

3.1. Increasing density method

To compare with method of increasing density, the model ground was compacted in improved area. Figure 4 shows the procedure of making compacted model ground. First, dry sand was poured into the water until 50mm thickness in the container, and compacted sand block of designated density was made in another container and was frozen. Second, this frozen block was put on the 50mm thickness ground. After putting the block, dry sand was poured into the water around the frozen block until the target height. During this time, the frozen block was being hung. After that, the model ground with frozen block was left overnight to thaw it. Finally, take off the lifting tool, and then preparation of making compacted ground was completed. Ground relative density around the frozen block was approximately 50% due to this method. The improved grounds were 60%, 70%, 80% and 90% in the relative density.

3.2. Log piling method

Figure 5 shows the procedure of making model ground by log piling. First, measured saturated sand was prepared in the container. Next, sand in the container was mixed sufficiently by jet from the nozzle while draining the top clear water. After mixing and sedimentation of particles, to make the ground of 50% relative density, the model ground was shaken a little until thickness of the model ground height is 300mm. Finally, pencil-shaped logs were piled into the model ground at designated intervals. Piling intervals of log were 8D(a_s=1.2%, D_r=57%), 5D(a_s=3.1%,D_r=68%), 4D(a_s=4.9%, D_r=79%), 3D(a_s=8.7%, D_r=98%). Here, D is diameter of log, a_s is improvement rate (%) and D_r is assumed relative density (%).

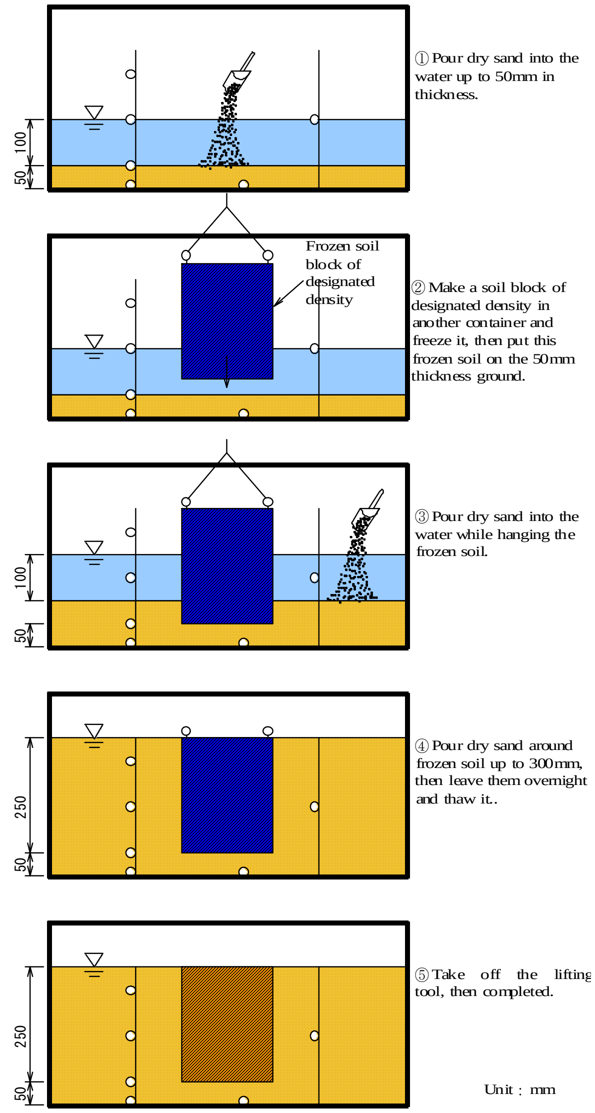


Figure 4. Procedure of making compacted model ground

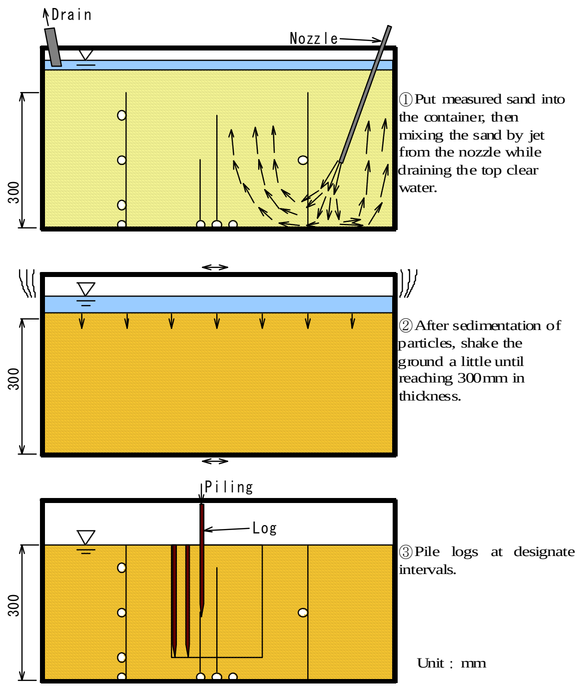


Figure 5. Procedure of making model ground by log piling

4. RELATIONSHIP BETWEEN INPUT ACCELERATION AND SETTLEMENT

Figure 6 shows relationship between input acceleration and cumulative amount of settlement from the result of the ground improved by increasing density. Brocken line indicates result of no improvement (Dr=50%). Large settlement occurred more than 20mm at 100gal in the case of no improvement. In other cases, large settlement occurred at 150gal and more than 150gal, and settlement decreases with increasing density. As a result, it can be understood that increasing density is effective to improve a liquefiable ground as many researchers know. However, some amount of settlement occurred even at large relative density such as 80% and 90%. Reason of this might be that unimproved ground remained under the dense improved ground, or since unimproved ground remained around the improved ground and this area liquefied at smaller input acceleration, improved area shook hard by inertia of the weight and the improved area was gradually broken from the outside.

Figure 7 shows relationship between input acceleration and cumulative amount of settlement from the result of the ground improved by log piling. Results of no improvement and 90% relative density were also shown in this figure. It can be seen that settlement decreases with decreasing the interval. In addition, results of 4D and 5D seem to be more effective than those of increasing density.

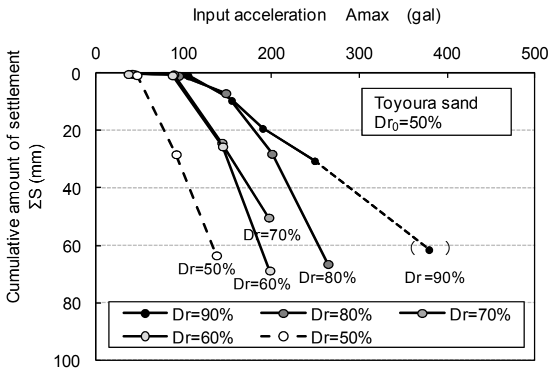


Figure 6. Relationship between input acceleration and cumulative amount of settlement by increasing density

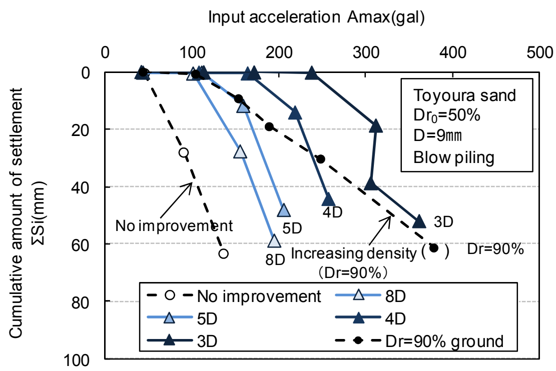
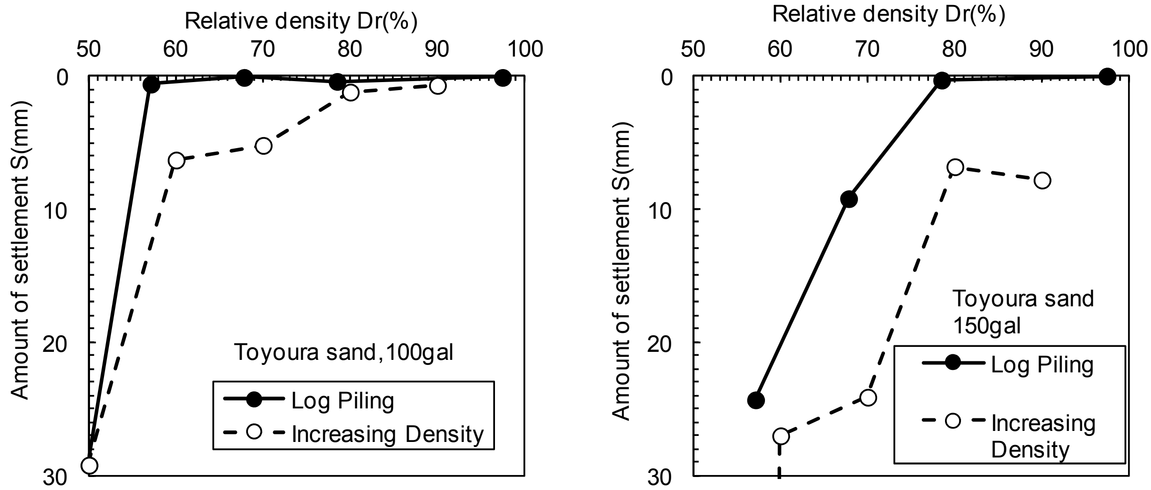


Figure 7. Relationship between input acceleration and cumulative amount of settlement by log piling



(a) 100gal

(b) 150gal

Figure 8. Relationship between relative density and amount of settlement

5. COMPARISON BETWEEN INCREASING DENSITY AND LOG PILING METHOD

Figure 8 shows relationship between relative density and amount of settlement at 100gal and 150gal input acceleration to compare between increasing density and log piling method. Relative density in the ground between log piles was calculated based on the assumption that particles do not move vertical direction. Settlements of the ground improved by log piling were less than those by increasing density method and it can be understood that log piling is more effective than increasing density under the same relative density. The reason of this effectiveness of log piling for liquefaction mitigation can be thought that log piling improves the ground not only to increase density but also to increase bearing capacity, to increase stiffness of the ground as composite ground and to increase confining pressure due to an increase in lateral earth pressure. Consequently, if the ground density between log piles is calculated assuming particles only move laterally and liquefaction resistance is estimated by this density, safe side design can be possible for liquefaction mitigation.

6. CONCLUSION

(1) Effect of liquefaction mitigation increases with decreasing interval between logs.

(2) Effect of liquefaction mitigation by log piling method is more effective than that by increasing density method.

(3) Safe side design for log piling method can be possible for liquefaction mitigation due to estimating liquefaction resistance from calculated ground density between piling logs.

ACKNOWLEDGEMENT

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